SUMMARY OF MORTALITY STATISTICS AND FOREST HEALTH MONITORING RESULTS FOR THE NORTHEASTERN UNITED STATES

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Abstract: The USDA Forest Service's Forest Inventory and Analysis (FIA) program and the Forest Health Monitoring (FHM) program maintain networks of sample locations providing coarse-scale information that characterize general indicators of forest health. Tree mortality is the primary FIA variable for analyzing forest health. Recent FIA inventories of New York, Pennsylvania, and West Virginia reveal that the current rate of mortality, expressed as percent of basal area of live trees, is 1.01. The Virginia Pine (*Pinus virginiana*) and Pitch Pine (*Pinus rigida*) forest types, growing along the ridges of the Appalachian Mountains, had high rates of mortality compared to the average rate for the study region. By diameter class, mortality rates were above average in the two smallest diameter classes and the largest diameter class. Counties with above-average mortality were concentrated in northern New York, the southern half of Pennsylvania, and in a patchwork pattern in West Virginia. The top five mortality species/species groups were American elm (*Ulmus americana*), balsam fir (*Abies balsamea*), black locust (*Robinia pseudoacacia*), aspen (*Populus grandidentata* and *P. tremuloides*), and Virginia pine. The FHM program used crown density, foliage transparency, and crown dieback as indicators of forest health. The most current FHM results indicate that 97.3% of hardwood sample trees in New England and 97.5 in the three Mid-Atlantic states had crown density of greater than 20%. In terms of foliage transparency, 98.9% of the hardwood sample trees in New England had foliage transparency of 30% or less. For the Mid-Atlantic states, 92.5% had foliage transparency of 30% or less. Also, 95.8 and 98.1% of the hardwood sample trees had crown dieback of 20% or less in the New England and Mid-Atlantic regions, respectively.

INTRODUCTION

Forest health has become a dominant issue within the forestry community. Although a firm consensus of what forest health is and how it should be measured is still evolving, it is important to seek sources of information to shed light on this important issue. The USDA Forest Service's Forest Inventory and Analysis (FIA) and Forest Health Monitoring (FHM) programs maintain networks of sample locations that provide coarse information that addresses general aspects of forest health. This information can help other researchers and policymakers in directing resources toward more detailed studies of species and regions that may be experiencing health-related problems. Because all states do not participate in the FHM program or have recent FIA inventories, it is our intent to combine the most recent findings of each program to characterize forest health in the northeastern United States.

METHODS

The FIA Program

The FIA program has been conducting successive forest inventories on a state-by-state basis since the 1930's. The northeastern FIA (NE-FIA) maintains a grid of roughly 16,000 sample locations across 13 states, from Ohio and West Virginia northward and eastward to Maine.

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Sample locations in each northeastern state are measured every 10 to 15 years using a two-phase sample design that comprises an aerial-photo interpretation phase and a ground-sample phase. In the photo-interpretation phase, large numbers of temporary photopoints are classified as forest and nonforest land. The intensity of photo sampling is high due to the low cost of aerial photo sampling relative to ground sampling. The photo sample is used in conjunction with U.S. Bureau of Census data on land area to produce estimates of forest land. In addition to classifying land use at each photopoint, a volume-per-acre class is assigned. Each ground-sample location is photointerpreted in the same manner as the photopoints. The ground locations are then chosen for measurement in proportion to the distribution of photopoints by volume-per-acre class.

Ground locations are visited to verify photo interpretation and to collect a suite of location- and tree-level measurements. Over the years, the northeastern FIA has used a variety of variable- and fixed-radius plot designs. The set of sample locations includes both remeasured locations and new ground locations. Among the location variables are slope, aspect, physiographic class, and stand origin. Tree data include variables such as species, diameter at breast height (dbh), tree history (live, cut, dead), bole length, and tree grade. Tree measurements are used to compile additional location variables such as forest type, stand size, and stand density. Other derived variables include growing-stock volume, net growth, removals, and mortality. Expansion factors for individual trees and sample locations (derived from the aerial-photo sample) are then used to compile population estimates for the state of interest. Each sample location represents roughly 5,000 to 10,000 acres of forest land.

Three of NE-FIA's most recent inventories are for Pennsylvania (Alerich 1993), New York (Alerich and Drake 1995), and West Virginia (DiGiovanni 1990). Tree mortality is the primary quantitative measure we have for assessing forest health using FIA data. Mortality estimates are computed using remeasured sample locations. The estimates represent changes that have occurred between the two most recent inventories. The following is sample information for the three Mid-Atlantic states:

State	Inventory period	Number of sample locations	Number of sample trees
New York	1980 to 1992	2,457	39,134
Pennsylvania	1978 to 1988	1,938	33,365
West Virginia	1975 to 1988	1,253	14,785

Mortality is expressed on an annual basis to provide information that can be compared among states, regions, species, and forest types. For this study, mortality estimates were indexed as a percentage of total basal area, numbers of trees, and growing-stock volume. Because we lack digital data for earlier inventories, we were unable to compile longer term trend information on mortality. Also, the sample is limited to trees that were at least 5.0 inches in dbh at the time of the previous inventory because estimates for smaller trees are not based on paired measurements.

The FHM Program

The FHM program first established plots in 1990 in the six New England states. As of 1995, the northern FHM program had 1,294 plots in 14 states, 672 of which were classified as forested. Currently, the northern states are grouped into three broad geographic regions: New England (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont); Mid-Atlantic (Delaware, Maryland, New Jersey, Pennsylvania, and West Virginia); and Lake States (Michigan, Minnesota, and Wisconsin). Plots were established in Delaware, Maryland, and New Jersey in 1991; in Michigan, Minnesota, and Wisconsin in 1994; and in Pennsylvania and West Virginia in 1995. Results from plots established in the New England and Mid-Atlantic regions are discussed here.

The FHM program, which combines research by the USDA Forest Service, state agencies, and other federal agencies, began as a part of the Environmental Monitoring and Assessment Program (EMAP) of the U.S. Environmental Protection Agency. EMAP developed a systematic sampling grid that covers North America. A sample location associated with each point on this grid is classified as forested or not forested. If a location is not forested, it is maintained in the sample and revisited every 4 years to determine whether it has become forested. If a plot is forested, location- and tree-level data are collected. Each forested location is a cluster of four fixed-radius, 1/24-acre circular subplots spaced 120 feet apart in a triangular formation (one center subplot with three subplots at the vertices of an equilateral triangle centered around the first subplot).[2]

When a sample location is established, location- and tree-level data are collected. Location data include location and physiographic information, understory vegetation assessments, and land-use information. Tree-level data include species, dbh, and assessments of crown condition, such as crown dieback, foliage transparency, and crown density. Location information and some tree data (e.g., dbh) are updated every 4 years. Data on crown condition are collected annually on forested plots.

The definitions of the three crown variables included in this report are:

Crown Dieback: Branch mortality that begins at the terminal portion of a branch and proceeds toward the trunk and/or base of the live crown.

Foliage Transparency: Amount of skylight visible through the live, normally foliated portion of the crown or branch.

Crown Density: Amount of crown branches, foliage, and reproductive structures that block visible light through the crown (Tallent-Halsell 1994).

Data for these variables are recorded in 5% classes from 0 to 100 (0-5, 6-10, etc.). Data are grouped for each variable and reported here as the percentage of trees in each group.

RESULTS

Recent FIA Inventories

The average rates of mortality for all states combined were 1.01, 1.21, and 0.75% for basal area, numbers of trees, and growing-stock volume, respectively (Table 1). Because longer term trend data for mortality are unavailable, it is difficult to qualify estimates as high or low. The overall averages provide benchmarks to put mortality estimates for specific classes and species into perspective. Usually, the rate expressed as numbers of trees is higher than the others because mortality often is concentrated in smaller size classes that contain more trees. The rate expressed in growing-stock volume tends to be lower because it excludes rough and rotten trees, which tend to die more often than growing-stock trees due to preexisting conditions such as butt rot. The rate based on basal area probably is the most useful because it accounts for all trees that were alive at the previous inventory and is not limited to trees selected for management (growing stock). Mortality rates were slightly higher than the overall averages in Pennsylvania. Mortality rates in New York and West Virginia were below the averages and similar in magnitude.

Results by forest-type group reflect species composition of the group, site-species relationships, and dynamic factors affecting the site, such as weather, insects, disease, and anthropogenic influences. Mortality averaged 1.01% using basal area as a measure and ranged from 1.62% for the Loblolly-Shortleaf group to 0.74% for the Red-White-Jack Pine group (Table 2). Loblolly-Shortleaf stands in the Mid-Atlantic states comprise primarily the Virginia Pine (*Pinus virginiana* Mill.) and Pitch Pine (*Pinus rigida* Mill.) forest types, as well as some Eastern Redcedar (*Juniperus virginiana* L.) and Table-Mountain Pine (*Pinus pungens* Lamb). The Virginia Pine and Pitch Pine types often occupy dry, rocky sites of the Appalachian Mountains. Common associates include a variety of oaks (*Quercus* spp.), red maple (*Acer rubrum* L.), blackgum (*Nyssa sylvatica* Marsh.), and miscellaneous species.

[2]Conkling, B.L. and G.E. Byers., eds. 1992. Forest health monitoring field methods guide (national guide). Unpublished report on file at U.S. Environmental Protection Agency, Office of Research and Development, Research Triangle Park, NC. 434 p.

Table 1. Average annual mortality rate and standard error (SE) expressed as percent of basal area of live trees, numbers of live trees, and growing-stock volume, New York 1980-1992, Pennsylvania 1978-1988, and West Virginia 1975-1988

State	Basal area Estimate	SE	No. of trees Estimate	SE	Growing-stock volume Estimate	SE
New York	0.96	.02	1.11	.02	0.69	.02
Pennsylvania	1.07	.03	1.30	.03	0.84	.03
West Virginia	0.98	.03	1.23	.03	0.68	.03
All states combined	1.01	.01	1.21	.01	0.75	.01

Table 2. Average annual mortality rate and standard error (SE) expressed as percent of basal area of live trees, numbers of live trees, and growing-stock volume by forest-type group, New York 1980-1992, Pennsylvania 1978-1988, and West Virginia 1975-1988

Forest-type group	Basal area Estimate	SE	No. of trees Estimate	SE	Growing-stock volume Estimate	SE
Loblolly-Shortleaf[1]	1.62	.19	1.72	.23	1.35	.17
Aspen-Birch	1.32	.13	1.55	.15	1.11	.12
Elm-Ash-Maple	1.29	.09	1.47	.10	1.04	.09
Spruce-Fir	1.23	.11	1.35	.14	1.10	.11
Oak-Hickory	1.07	.02	1.31	.03	0.81	.03
Oak-Pine	1.01	.09	1.21	.10	0.82	.10
Maple-Beech-Birch	0.94	.02	1.10	.02	0.66	.02
Miscellaneous	0.80	.26	1.08	.38	0.89	.51
Red-White-Jack pine	0.74	.04	0.97	.05	0.55	.03
All groups combined	1.01	.01	1.21	.01	0.75	.01

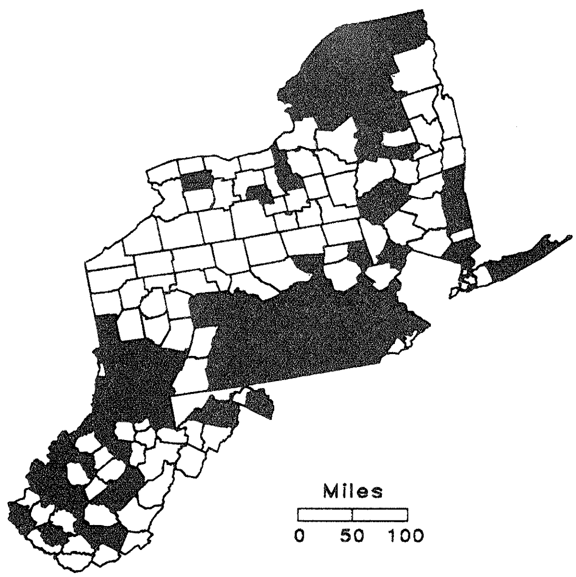
[1]Includes Virginia Pine, Pitch Pine, Table-Mountain Pine, and Eastern Redcedar forest types.

Throughout the infestation area of gypsy moth (*Lymantria dispar* L.), along the ridges of the Appalachian Mountains, the Virginia Pine and Pitch Pine communities were particularly susceptible to defoliation and subsequent mortality. The Aspen-Birch, Elm-Ash-Maple, and Spruce-Fir groups also had high mortality rates. The common thread among these groups is that they have characteristic species that are experiencing high mortality, such as aspen, American elm, and balsam fir.

Stocking often is mentioned as a possible factor that influences tree mortality. The results of this study show that mortality rates were similar by stocking class (Table 3). Rates for stands in the 140% and higher stocking class were roughly one-third to one-half higher than the overall averages, but were associated with high standard errors. Rates were slightly lower in the most sparsely stocked (0 to 19% stocked) stands.

The overall averages allow us to focus on mortality rates that are "above average" and that may indicate prospective issues related to forest health. The average mortality rate as a percentage of live tree basal area was 1.01%. These data can be displayed by county to provide a general idea of the spatial distribution of mortality (Figure 1a). Counties with above-average mortality were concentrated in northern New York and southern Pennsylvania. Above-average mortality was scattered in West Virginia.

a)



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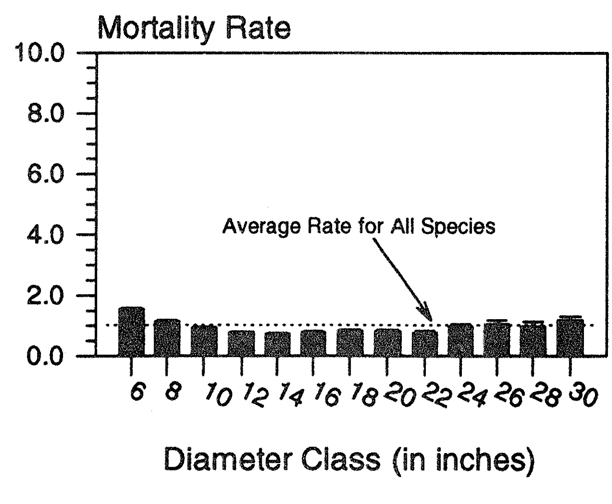

Figure 1. (a) Counties with above-average annual rates of mortality as percentage of all species/species groups basal area of live trees (5.0 inches in diameter and larger); and (b) Average annual rate of mortality of all species/species groups live tree basal area by diameter class where brackets indicate one standard error (standard errors less than 0.1 are obscured).

Table 3. Average annual mortality rate and standard error (SE) expressed as percent of basal area of live trees, numbers of live trees, and growing-stock volume by stocking class, New York 1980-1992, Pennsylvania 1978-1988, and West Virginia 1975-1988

Stocking Class (percent)	Basal area Estimate	SE	No. of trees Estimate	SE	Growing-stock volume Estimate	SE
0 to 19	0.88	.06	0.99	.08	0.71	.06
20 to 39	0.98	.04	1.14	.05	0.74	.04
40 to 59	0.99	.03	1.17	.03	0.71	.03
60 to 79	0.98	.02	1.20	.03	0.73	.02
80 to 99	1.08	.03	1.33	.04	0.82	.03
100 to 119	0.99	.05	1.25	.06	0.73	.05
120 to 139	0.89	.09	1.15	.12	0.54	.09
140 and higher	1.34	.40	1.31	.30	1.16	.40
All classes combined	1.01	.01	1.21	.01	0.75	.01

Table 4. Average annual mortality rate and standard error (SE) expressed as percent of basal area of live trees, numbers of live trees, and growing-stock volume by species/species group for species with above average mortality, New York 1980-1992, Pennsylvania 1978-1988, and West Virginia 1975-1988

Species/Species Group	Basal area Estimate	SE	No. of trees Estimate	SE	Growing-stock volume Estimate	SE
American elm	3.28	.20	3.26	.22	3.22	.22
Balsam fir	2.64	.23	2.38	.21	2.71	.26
Black locust	2.40	.14	2.75	.15	1.61	.15
Aspen	2.22	.10	2.45	.11	1.91	.10
Virginia pine	1.96	.15	1.97	.17	1.87	.16
Birch	1.37	.05	1.61	.06	1.00	.05
Chestnut Oak	1.34	.07	1.56	.08	1.18	.07
Black Walnut	1.24	.18	1.19	.20	0.87	.19
Red spruce	1.16	.09	1.36	.12	1.07	.09
American beech	1.09	.05	0.89	.05	0.64	.05

The distribution of mortality by diameter class (Figure 1b) revealed above-average rates in the two smallest diameter classes and the largest diameter class. This fits with the notion that as northeastern forests mature, smaller trees are being crowded out. Also, large "older" trees may be dying as middle-aged trees compete for growing space.

Ten species/species groups out of 23 were identified as having above average mortality (Table 4). Five species had roughly double the average rate of mortality. American elm (*Ulmus americana* L.) had the highest rate at 3.28, or more than triple the average rate. The impact of a wilt fungus (*Ceratocystis ulmi* (Buisum.) C. Moreau), the agent of Dutch elm disease, has been well documented since its introduction in 1930 (Burns and Honkala 1990b). Concentrations of dead American elm trees were highest in eastern New York (Figure 2a). Other than a high rate of mortality in some large diameter classes, mortality rates were similar in other size classes (Figure 2b).

Balsam fir (*Abies balsamea* (L.) Mill.) ranked second in mortality with a rate of 2.64%. Spruce budworm (*Choristoneura fumiferana* (Clemens)), the primary damaging agent of balsam fir, thrives in stands with a high proportion of fir. Most of the mortality in the Mid-Atlantic states was in northeastern New York, where balsam fir is abundant (Figure 3a). Larger trees in the sample had the highest mortality rates (Figure 3b).

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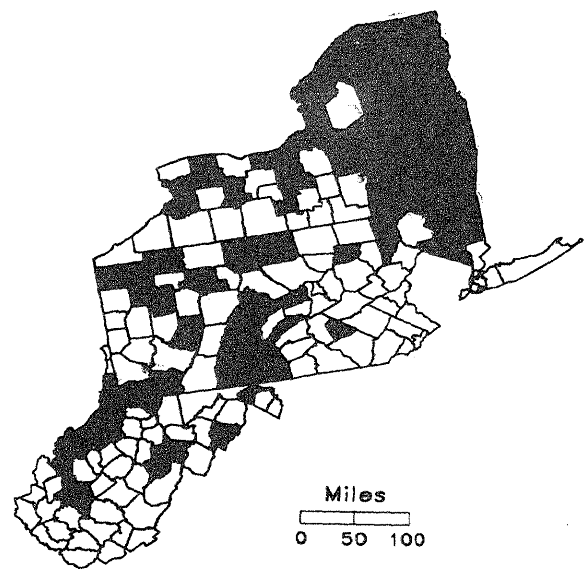

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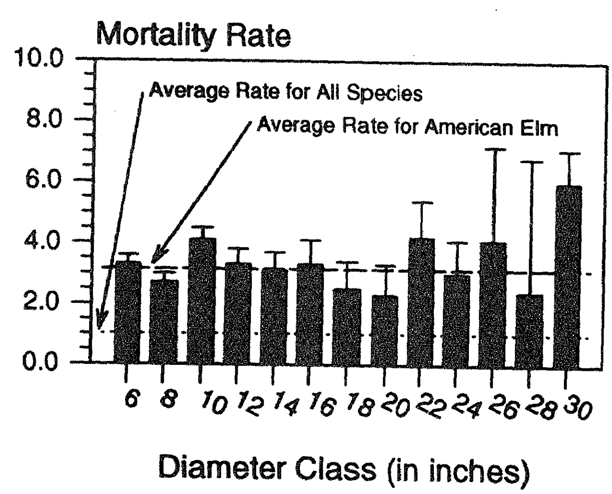


Figure 2. (a) Counties with above-average annual rates of mortality as percentage of American elm basal area of live trees (5.0 inches in diameter and larger); and (b) Average annual rate of mortality of American elm live-tree basal area by diameter class (brackets indicate one standard error).

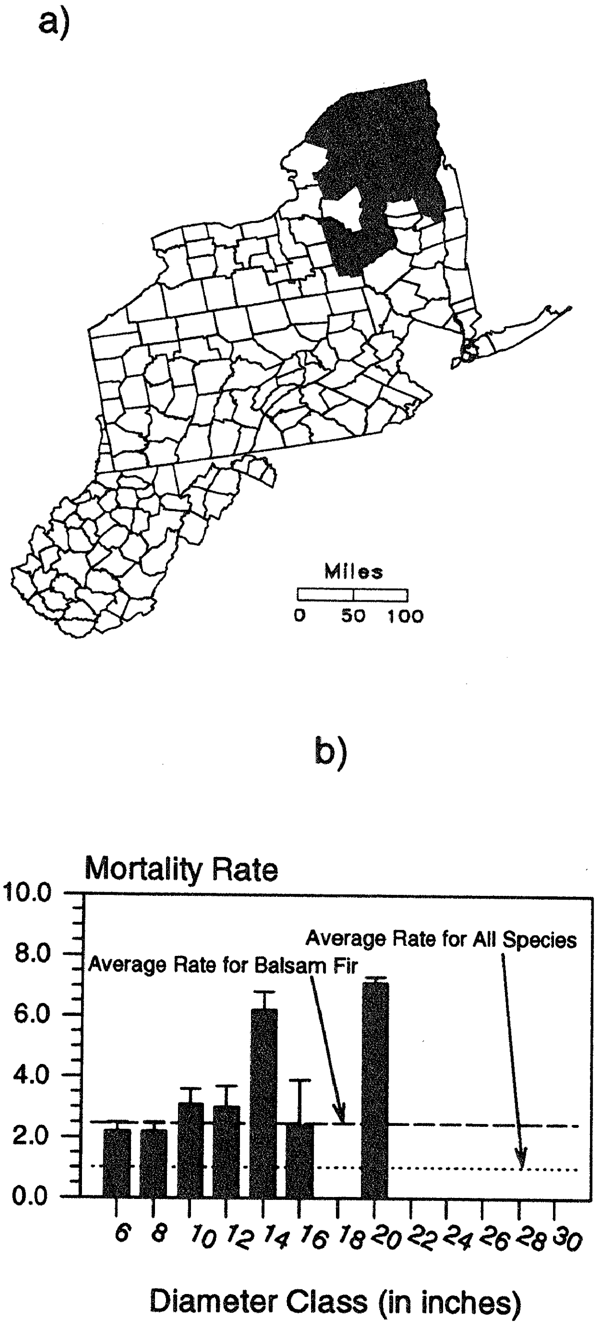


Figure 3. (a) Counties with above-average annual rates of mortality as percentage of balsam fir basal area of live trees (5.0 inches in diameter and larger); and (b) Average annual rate of mortality of balsam fir live-tree basal area by diameter class (brackets indicate one standard error).

Black locust (*Robinia pseudoacacia*) had the third highest mortality rate (2.40%). Areas with above average mortality were concentrated in West Virginia and southwestern Pennsylvania (Figure 4a). By diameter class, mortality rates were highest in the smallest diameter class (Figure 4b). Black locust is a pioneer species that is relatively short lived in the development of a typical stand (Burns and Honkala 1990b). Also, black locust usually is a small component in forest stands. It accounts for less than 1% of the growing-stock volume in the study region.

Aspen (*Populus grandidentata* Michx. and *P. tremuloides* Michx.) had the fourth highest mortality. Aspen is another species whose relatively high mortality rate (2.22%) is surprising. Aspen mortality was prevalent in counties where it is most common, primarily in Pennsylvania and New York (Figure 5a). Mortality was average or below average in all but the smallest and largest diameter classes (Figure 5b). Aspen mortality in the largest class was roughly twice the average rate for that species, possibly due to poor vigor in relation to other species in stands in advanced stages of development. Aspen is highly intolerant of shade and relatively short lived.

Virginia pine ranked fifth in mortality with a rate of 1.96% with most of the mortality in West Virginia and some mountainous counties in Pennsylvania (Figure 6a). Mortality of Virginia pine was spread relatively evenly over the range of diameter classes (Figure 6b). A pioneer species that regenerates on mineral soil and is intolerant of shade, Virginia pine often is replaced by deciduous species as a normal part of stand development (Burns and Honkala 1990a).

Species with mortality rates higher than the overall average (at least 30% higher) were the birches (*Betula* spp.) and chestnut oak (*Quercus prinus* L.) (Table 4). Other species with above-average rates are black walnut (*Juglans nigra* L.), red spruce (*Picea rubens* Sarg.), and American beech (*Fagus grandifolia* Ehrh.).

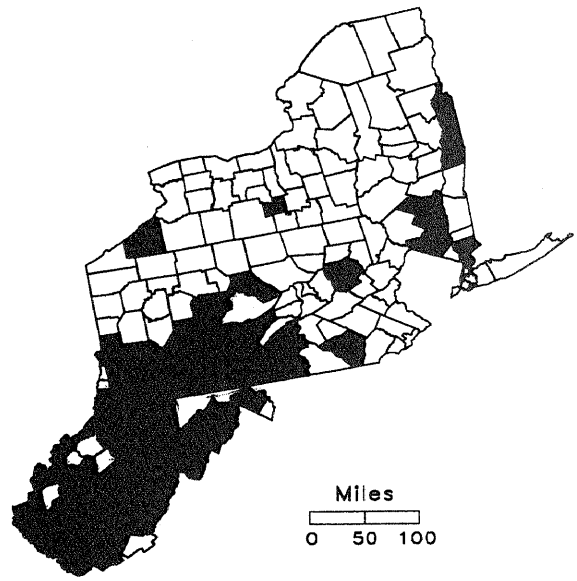
Recent FHM Inventories

The FHM program has 480 sample locations in 11 states in New England and the Mid-Atlantic states. Of these, 249 are forested on all or part of the sample. In New England, 79% of the area covered by the 263 locations is forested. In the Mid-Atlantic states, 51% of the area covered by 217 locations is forested.

In 1995, there were 6,020 live trees larger than 5.0 inches dbh on the New England FHM sample locations. Of these, 3,375 were hardwood species (Table 5). Red maple, sugar maple (*Acer saccharum* Marsh.), and paper birch (*Betula papyrifera* Marsh.) made up 52% of the hardwood sample in New England. Yellow birch (*Betula alleghaniensis* Britton), American beech, aspen, northern red oak (*Quercus rubra* L.), and white/green ash (*Fraxinus americana* L. and *F. pennsylvanica* Marsh.) made up another 33% of the sample. More than 90% of the trees in the white/green ash group were white ash.

There were 2,460 live trees on the FHM sample locations in the mid-Atlantic states, 2,275 of which were hardwood species. Red maple, white oak, black cherry (*Prunus serotina* Ehrh.), sugar maple, northern red oak, various hickory species (*Carya* spp.), American beech, and sweetgum (*Liquidambar styraciflua* L.) made up 54% of the sample.

a)



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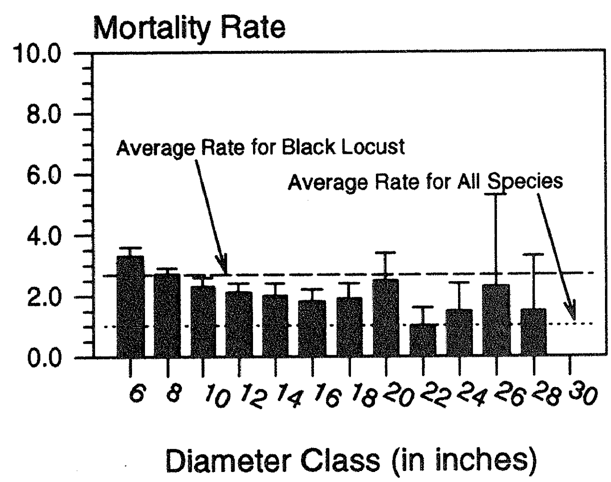

Figure 4. (a) Counties with above-average annual rates of mortality as percentage of black locust basal area of live trees (5.0 inches in diameter and larger); and (b) Average annual rate of mortality of black locust live-tree basal area by diameter class (brackets indicate one standard error).

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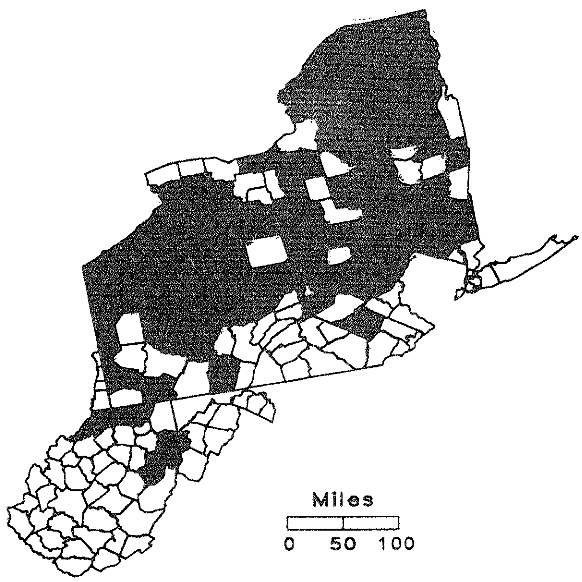

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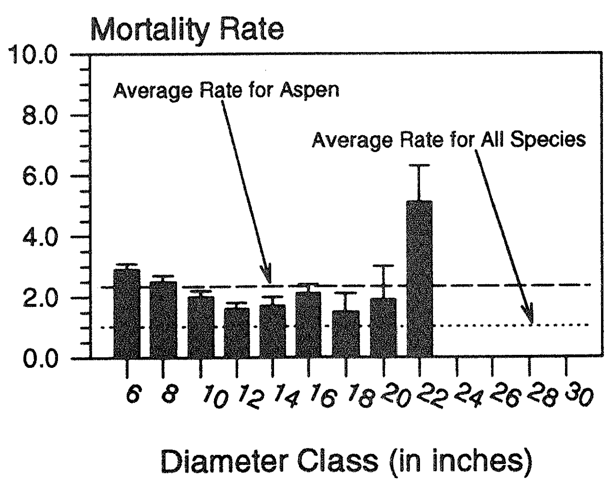

Figure 5. (a) Counties with above-average annual rates of mortality as percentage of aspen basal area of live trees (5.0 inches in diameter and larger); and (b) Average annual rate of mortality of aspen live-tree basal area by diameter class (brackets indicate one standard error).

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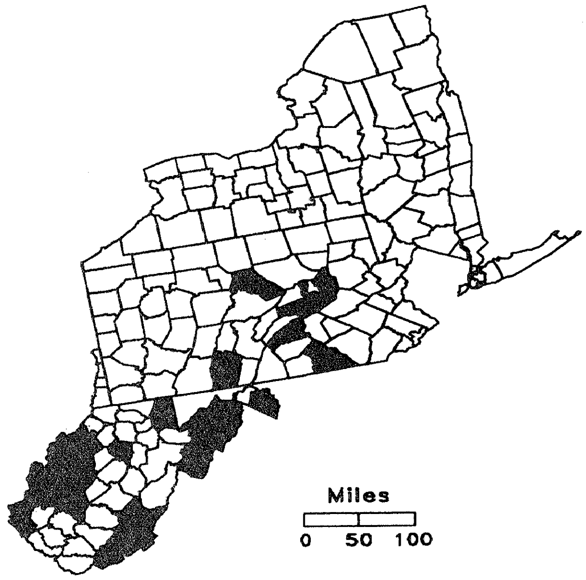

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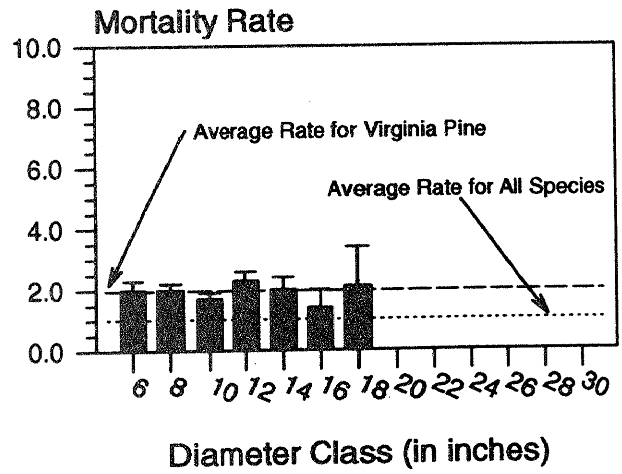

Figure 6. (a) Counties with above-average annual rates of mortality as percentage of Virginia pine basal area of live trees (5.0 inches in diameter and larger), and (b) Average annual rate of mortality of Virginia pine live-tree basal area by diameter class (brackets indicate one standard error).

Table 5. Distribution of live trees of major hardwood species on FHM sample locations in New England and Mid-Atlantic states by crown-density class[3]

Species	Sample size	Crown density Good (51+%)	Average (21-50%)	Poor (1-20%)
	Number	---- Percent of sampled trees ----		
		New England		
Red maple	991	30.4	66.4	3.2
Sugar maple	448	48.4	50.2	1.3
Paper birch	305	41.6	56.7	1.6
Yellow birch	267	52.4	46.1	1.5
American beech	249	29.3	67.1	3.6
Aspen	221	26.7	66.5	6.8
Northern red oak	213	38.5	60.1	1.4
White/green ash	182	39.0	56.6	4.4
Softwoods	2,645	33.4	64.3	2.3
Hardwoods	3,375	38.8	58.5	2.7
All species	6,020	36.4	61.1	2.5
		Mid-Atlantic		
Red maple	414	56.8	39.1	4.1
White oak	193	53.4	44.6	2.1
Black cherry	128	52.3	44.5	3.1
Sugar maple	127	63.8	35.4	0.8
Northern red oak	112	63.4	36.6	0.0
Hickory	104	75.0	25.0	0.0
American beech	73	63.0	35.6	1.4
Sweetgum	62	59.7	40.3	0.0
Softwoods	203	35.5	63.1	1.5
Hardwoods	2,257	60.2	37.3	2.5
All species	2,460	58.2	39.4	2.4

Crown Density. Approximately 97.3% of hardwood trees in New England had crown density of greater than 20% (Table 5). These percentages were consistent with results from previous years. For both aspen and white/green ash, more than 4% of the trees had crown densities of 20% or less.

[3] Barnett, C.J.; Mielke M.; Twardus, D.; Miller-Weeks, M. Northern forest health monitoring: 1995 summary reports. USDA, Forest Service, Northeastern Forest Experiment Station and Northern Area, State and Private Forestry. In prep.

Table 6. Distribution of live trees of major hardwood species on FHM sample locations in New England and Mid-Atlantic states by foliage-transparency class[3]

Region/Species	Sample size	Foliage transparency Normal (0-30%)	Moderate (31-50%)	Severe (51+%)
	Number	---- Percent of sampled trees ----		
New England				
Red maple	991	99.1	0.4	0.5
Sugar maple	448	99.8	0.0	0.2
Paper birch	305	97.7	1.6	0.7
Yellow birch	267	99.3	0.0	0.7
American beech	249	99.6	0.4	0.0
Aspen	221	98.2	1.8	0.0
Northern red oak	213	99.5	0.0	0.5
White/green ash	182	97.8	0.5	1.6
Softwoods	2,645	99.0	0.9	0.1
Hardwoods	3,375	98.9	0.6	0.5
All species	6,020	99.0	0.7	0.3
Mid-Atlantic				
Red maple	414	93.2	4.4	2.4
White oak	193	95.3	3.1	1.6
Black cherry	128	77.3	18.0	4.7
Sugar maple	123	96.9	1.6	1.6
Northern red oak	112	92.9	7.1	0.0
Hickory	104	99.0	1.0	0.0
American beech	73	94.5	4.1	1.4
Sweetgum	62	100.0	0.0	0.0
Softwoods	203	90.6	8.4	1.0
Hardwoods	2,257	92.5	5.8	1.7
All species	2,460	92.3	6.1	1.6

In the mid-Atlantic region, 97.5% of hardwood trees had crown density of greater than 20%. Red maple had 4.1% of trees in the 20% or less class. Black cherry was the only other species with more than the 2.4% average for crown density of 20% or less.

Foliage transparency. In New England, 98.9% of hardwood trees were classified as having less than 30% foliage transparency (Table 6), compared to 98.7 and 98.9% in 1993 and 1994, respectively. Trees in the white/green ash group had three times the average percentage of trees in the greater than 50% transparency class. Aspen had three times the average percentage of trees in the moderate transparency class.

For Mid-Atlantic states, 92.3% of all the trees had foliage transparency of less than 30% in 1995, compared to 97.3% in 1994. The number of sample locations in this region increased significantly in 1995 by the addition of plots in Pennsylvania and West Virginia. Black cherry had the highest levels of foliage transparency with 18.0% in the 31-50% class and 4.7% in the greater than 50% class. Northern red oak also had a higher than average percentage of trees in the 31-50% class.

Crown Dieback. In New England, 95.8% of the hardwood trees on FHM plots were classified as having crown dieback of 20% or less (Table 7). Hardwoods had higher percentages in the 6-20%, 21-50%, and greater than 50% classes than did softwoods. The percentage of white and green ash trees in the 21-50% and greater than 50% classes decreased from 10.2% in 1994 to 8.8% in 1995. There were 8.6% of the aspen trees in the 21-50% and greater than 50% classes. American beech had a slightly higher than the average percentage of trees in the 21-50% and greater than 50% classes.

In the Mid-Atlantic states, 98.1% of the hardwood trees had crown dieback 20% or less. No single species had more than 3.0% of trees in the moderate class. However, northern red oak had nearly double the average percentage of trees in the light and moderate classes, with 12.5 and 1.8%, respectively.

DISCUSSION

The FIA and FHM programs are providing valuable information on forest health. The FIA mortality data provide estimates of overall averages that allow comparisons among classes of forest and tree species, as well as coarse spatial information. Still, it is difficult to qualify mortality rates as high or low because there is little published information on this topic. In the northeast, we are further constrained by not having digital data for more than the current inventory. And the FIA data have other limitations. Because dead trees are relatively rare within the FIA sample compared to live "survivor" trees, mortality estimates have relatively high sampling errors. Also, it can be difficult to distinguish tree removal from mortality in areas where salvage cuttings occur. If an FIA field crew encounters a tree stump, the tree often is classified as cut even though it may have died before removal. Another limitation is that FIA data usually are insufficient to establish relationships of cause and effect. The reason for this is that FIA typically measures effects, or the dependent variable, rather than causal factors, or independent variables (Schreuder and Thomas 1991). Additional research is needed to determine the kinds of variables FIA could collect that would elucidate causation and that are economically feasible. The lag between the time when damage agents attack a tree and the time when the tree dies also should be considered in our analyses. For example, during the recent inventory of Pennsylvania, large-scale outbreaks of insects were occurring in northwestern Pennsylvania (McWilliams and others 1996), but the trees were still alive. We know that since then, significant numbers of trees have died. Lastly, it is important to note that using mortality rates as a measure of forest health ignores the role of regeneration in replenishing forest stands.

The FHM sample results suggest that tree health is good in New England and the Mid-Atlantic states. However in New England, aspen had higher than average percentages of trees in the poor-density and moderate-transparency classes. Also in 1995, there were reports of increased activity by the forest tent caterpillar (*Malacosoma disstria* Hubner) in the aspen-birch forest types.[3] Defoliation by forest tent caterpillar would reduce the density and increase transparency of the crowns of these trees. In New England, ash yellows continues to contribute to thin and dying crowns (i.e., low density, high transparency, high dieback) on these trees. Beech bark disease (*Nectria* spp.) is contributing to the higher than average dieback ratings on American beech. In the Mid-Atlantic states, the cherry scallop shell moth (*Calocalpe undulata* L.) likely contributed to the higher density and transparency ratings in black cherry. The elevated transparency and dieback in northern red oak probably was the result of scattered defoliation by gypsy moth and forest tent caterpillar.

Table 7. Distribution of live trees of major hardwood species on FHM sample locations in New England and Mid-Atlantic states by crown-dieback class[3]

Region/Species	Sample size	Crown dieback None (0-5%)	Light (6-20%)	Moderate (21-50%)	Severe (51+%)
	Number	----- Percent of sampled trees -----			
		New England			
Red maple	991	75.1	20.4	3.4	1.1
Sugar maple	448	84.2	12.7	1.8	1.3
Paper birch	305	79.0	17.1	2.0	2.0
Yellow birch	267	83.5	14.6	1.1	0.8
American beech	249	68.3	26.5	4.0	1.2
Aspen	221	64.7	26.7	7.2	1.4
Northern red oak	213	72.8	26.3	1.0	0.0
White/green ash	182	72.0	19.2	4.4	4.4
Softwoods	2,645	89.1	9.1	1.3	0.5
Hardwoods	3,375	76.4	19.4	2.9	1.3
All species	6,020	82.0	14.9	2.2	0.9
		Mid-Atlantic			
Red maple	414	90.6	7.3	1.5	0.7
White oak	193	95.9	2.6	0.5	1.0
Black cherry	128	92.2	7.8	0.0	0.0
Sugar maple	127	98.4	1.6	0.0	0.0
Northern red oak	112	85.7	12.5	1.8	0.0
Hickory	104	94.2	5.8	0.0	0.0
American beech	73	90.4	6.9	1.4	1.4
Sweetgum	62	95.2	3.2	1.6	0.0
Softwoods	203	97.0	3.0	0.0	0.0
Hardwoods	2,257	91.8	6.3	1.1	0.9
All species	2,460	92.2	6.0	1.0	0.8

On the basis of assessments of trees within the FHM sample network in the northeast, the hardwood resource seems to be doing well, with noted exceptions. Because the network was able to identify species with known problems or conditions, we expect that changing conditions in other species can also be identified.

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